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ABOUT DIRECT CP VIOLATION IN THE SYSTEM OF K^0 MESONS

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Параметр прямого нарушения CP-четности в системе K^0-мезонов

Работа посвящена вычислению параметра прямого нарушения CP-четности в слабых взаимодействиях в системе K^0-мезонов, которое возникает при смешиваниях и осцилляциях K_1^0-, K_2^0-мезонов через K_S-, K_L-мезонные состояния.

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About Direct CP Violation in the System of K^0 mesons

This work is devoted to computation of the parameter of direct CP violation by the weak interactions in the system of K^0 mesons at K_1^0-, K_2^0-meson mixings and oscillations via K_S-, K_L-meson states.

The investigation has been performed at the Veksler and Baldin Laboratory of High Energy Physics, JINR.

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1. INTRODUCTION

A phenomenological analysis of K^0-meson processes was done in work [1] (see also [2]). There nonunitary transformation and nonorthogonal states were used in obtaining K_S, K_L states. It was supposed that these states arise at CP violation. The expressions for these states have the following form:

$$
\begin{aligned}
K_S &= (K_1^0 + \varepsilon_0 K_2^0)/\sqrt{1+|\varepsilon_0|^2},\\
K_L &= (K_2^0 + \varepsilon_0 K_1^0)/\sqrt{1+|\varepsilon_0|^2},
\end{aligned}
\tag{1}
$$

and, on the contrary,

$$
\begin{aligned}
K_1^0 &= (K_S - \varepsilon_0 K_L)\frac{\sqrt{1+|\varepsilon_0|^2}}{1-\varepsilon_0^2},\\
K_2^0 &= (K_L - \varepsilon_0 K_S)\frac{\sqrt{1+|\varepsilon_0|^2}}{1-\varepsilon_0^2}.
\end{aligned}
\tag{2}
$$

Writing the wave function of K_L, K_S mesons in the form

$$
\begin{aligned}
K_S &= \frac{1-\varepsilon_0}{\sqrt{2(1+|\varepsilon_0|^2)}}\,\mathrm{e}^{-im_S t - \frac{\Gamma_S t}{2}},\\
K_L &= \frac{1-\varepsilon_0}{\sqrt{2(1+|\varepsilon_0|^2)}}\,\mathrm{e}^{-im_L t - \frac{\Gamma_L t}{2}},
\end{aligned}
\tag{3}
$$

and putting expression (3) into expression (2) and then taking the first term of (2) in the quadratic form on the absolute value, we obtain ($\hbar = 1$)

$$
\begin{aligned}
|K_1^0|^2 = &\frac{|1-\varepsilon_0|^2}{2(1-|\varepsilon_0|^2)}\times\\
&\times\left(\mathrm{e}^{-\Gamma_S t} + |\varepsilon_0|^2\,\mathrm{e}^{-\Gamma_L t} - 2|\varepsilon_0|\,\mathrm{e}^{-\frac{(\Gamma_S+\Gamma_L)t}{2}}\cos\left((m_L - m_S)t\right)\right).
\end{aligned}
\tag{4}
$$

In expression (4) a cross term appears which is responsible for oscillations. This term can be interpreted as oscillations between K_S, K_L states; i. e., these states are nonorthogonal ones. It is necessary to stress that in this approach it is supposed that at long distances from the source of K^0 mesons there mainly present K_L mesons and with probability $|\epsilon_0|$ also appear K_S mesons.

In the framework of quantum mechanics, if the states are wave vectors, expression (3) has to be written in the following form:

$$K_S(t) = \frac{1-\varepsilon_0}{\sqrt{2(1+|\varepsilon_0|^2)}} \mathrm{e}^{-im_S t - \frac{\Gamma_S t}{2}} K_S(0),$$
$$K_L(t) = \frac{1-\varepsilon_0}{\sqrt{2(1+|\varepsilon_0|^2)}} \mathrm{e}^{-im_L t - \frac{\Gamma_L t}{2}} K_L(0), \tag{5}$$

then after taking it in the quadratic form on the absolute value we get

$$|K_1^0|^2 = \frac{|1-\varepsilon_0|^2}{2(1-|\varepsilon_0|^2)} \left(\mathrm{e}^{-\Gamma_S t} + |\varepsilon_0|^2 \mathrm{e}^{-\Gamma_L t}\right). \tag{6}$$

For description of processes in the system of K^0 mesons in our previous work [3] the standard theory of oscillations was used.

In the system of K^0 mesons a sufficiently complex process takes place. At first strangeness is violated in weak interactions and, as a consequence of it, K^0, $\bar{K}^0$ mesons are transformed into superpositions of K_1^0, K_2^0 mesons (K_1^0, K_2^0 mesons are eigenstates of the weak interactions violating the strangeness and they have definite CP parities). Then follow oscillations of $K^0 \leftrightarrow \bar{K}^0$ mesons. Probability for K^0-, $\bar{K}^0$-meson oscillations is given by the following expression:

$$P(K^0 \to \bar{K}^0) = \frac{1}{4}\left[\mathrm{e}^{-\Gamma_1 t} + \mathrm{e}^{-\Gamma_2 t} - 2\mathrm{e}^{-\frac{(\Gamma_1+\Gamma_2)t}{2}} \cos\left((E_2 - E_1)t\right)\right]. \tag{7}$$

In the weak interactions there also exists violation of CP parity. Then K_1^0, K_2^0 mesons become superposition states of K_S, K_L mesons (K_S-, K_L-meson states are eigenstates of weak interactions violating CP parity). As a result, there appear oscillations between $K_1^0 \leftrightarrow K_2^0$ mesons. Just as a result of such transitions, there arise two pion decays at big distances from K^0 sources. The expression for probability of K_2^0-meson transition into K_1^0 has the following form:

$$P(K_2^0 \to K_1^o) = \frac{1}{4}\sin^2 2\beta\left[e^{-\Gamma_S t} + \mathrm{e}^{-\Gamma_L t} - 2\mathrm{e}^{-\frac{(\Gamma_S+\Gamma_L)t}{2}} \cos\left((E_L - E_S)t\right)\right].$$

If we take into account that $\cos\beta \simeq 1$, $\sin\beta \simeq \varepsilon$, we get ($\epsilon = \varepsilon^2, \varepsilon_0 \sim \epsilon$)

$$P(K_2^0 \to K_1^0) = \varepsilon^2\left[\mathrm{e}^{-\Gamma_S t} + \mathrm{e}^{-\Gamma_L t} - 2\mathrm{e}^{-\frac{(\Gamma_S+\Gamma_L)t}{2}} \cos\left((E_L - E_S)t\right)\right], \tag{8}$$

and probability for $P(K_1^0 \to K_1^0)$ transitions is

$$P(K_1^0 \to K_1^0) = \left[\mathrm{e}^{-\Gamma_S t} + \epsilon^2 \mathrm{e}^{-\Gamma_L t} + 2\epsilon\, \mathrm{e}^{-\frac{(\Gamma_S+\Gamma_L)t}{2}} \cos\left((E_L - E_S)t\right)\right], \quad (9)$$

and $P(K_2^0 \to K_2^0)$ is

$$P(K_2^0 \to K_2^0) = \left[\epsilon^2 \mathrm{e}^{-\Gamma_S t} + \mathrm{e}^{-\Gamma_L t} + 2\epsilon\, \mathrm{e}^{-\frac{(\Gamma_S+\Gamma_L)t}{2}} \cos\left((E_L - E_S)t\right)\right], \quad (10)$$

These oscillations arise against the background of $K^0 \to l^- \pi^+ \bar{\nu}_l$, $\bar{K}^0 \to l^+ \pi^- \nu_l$, $K_1^0 \to 2\pi$, $K_2^0 \to 3\pi$ and others decays.

Now we write out some expressions which we will use later. The connection between K_1^0, K_2^0 and K^0, $\bar{K}^0$ states and also K_1^0, K_2^0 and K_S, K_L states are given by the expressions [3]

$$K_1^0 = \frac{K^0 - \bar{K}^0}{\sqrt{2}}, \qquad K_2^0 = \frac{K^0 + \bar{K}^0}{\sqrt{2}},$$
$$K_1^0(t) = \cos\beta\, \mathrm{e}^{-iE_S t} K_S(0) + \sin\beta\, \mathrm{e}^{-iE_L t} K_L(0), \quad (11)$$
$$K_2^0(t) = -\sin\beta\, \mathrm{e}^{-iE_S t} K_S(0) + \cos\beta\, \mathrm{e}^{-iE_L t} K_L(0).$$

We can also connect K_S-, K_L-meson states with the K^0-, $\bar{K}^0$-meson states. Then

$$\begin{aligned} K^0 &= \frac{1}{\sqrt{2}}[(\cos\beta - \sin\beta)K_S + (\sin\beta + \cos\beta)K_L], \\ \bar{K}^0 &= \frac{1}{\sqrt{2}}[-(\sin\beta + \cos\beta)K_S + (\cos\beta - \sin\beta)K_L], \end{aligned} \quad (12)$$

at the inverse transformation we get

$$\begin{aligned} K_S &= \frac{1}{\sqrt{2}}[(\cos\beta - \sin\beta)K^0 - (\cos\beta + \sin\beta)\bar{K}^0], \\ K_L &= \frac{1}{\sqrt{2}}[(\cos\beta + \sin\beta)K^0 + (\cos\beta - \sin\beta)\bar{K}^0]. \end{aligned} \quad (13)$$

We can simplify the above expressions by taking into account that $\sin\beta \ll 1$ and then $\cos\beta \simeq 1$. Then expression (13) get the following form:

$$\begin{aligned} K_S &= \frac{1}{\sqrt{2}}[(1 - \varepsilon)K^0 - (1 + \varepsilon)\bar{K}^0], \\ K_L &= \frac{1}{\sqrt{2}}[(1 + \varepsilon)K^0 + (1 - \varepsilon)\bar{K}^0]. \end{aligned} \quad (14)$$

where we replaced $\sin\beta$ by ε.

2. DIRECT CP VIOLATION IN THE SYSTEM OF K^0 MESONS

2.1. Old Result Obtained in [1]. In work [1], where it is supposed that at big distances there are only K_S, K_L mesons, an expression was obtained for direct CP violation in the system of K^0 mesons. For this aim they compute the decay probability of K_S, K_L mesons into two pions assuming that CPT invariance takes place. Since pions are bosons, full wave functions have to be invariant at their transposition. Isospin of pion is equal to one $I = 1$ and final state at K_S-, K_L-meson decay must have isospin $I = 0, I_3 = 0$ or $I = 2$, $I_3 = 0$ (at transition of $K_{SL} \to 2\pi$ the rule $\Delta S = 1/2$ is realized). Then there appear the following 4 states:

$$\begin{aligned} &\langle \pi\pi, I = 0|H_W|K_S\rangle, \quad \langle \pi\pi, I = 2|H_W|K_S\rangle, \\ &\langle \pi\pi, I = 0|H_W|K_L\rangle, \quad \langle \pi\pi, I = 2|H_W|K_L\rangle. \end{aligned} \tag{15}$$

Using of Klebsh–Gordon coefficients, we can write two pion states in the form

$$\begin{aligned} \langle \pi^+\pi^-| &= \sqrt{\frac{1}{3}}\langle \pi\pi, I = 2| + \sqrt{\frac{2}{3}}\langle \pi\pi, I = 0|, \\ \langle \pi^0\pi^0| &= \sqrt{\frac{2}{3}}\langle \pi\pi, I = 2| - \sqrt{\frac{1}{3}}\langle \pi\pi, I = 0|, \end{aligned} \tag{16}$$

where $\pi^+\pi^- = (\pi_1^+\pi_2^- + \pi_2^+\pi_1^-)/\sqrt{2}$. We will take into account that there arise the following phase shifts due to pion interactions in final state — $e^{i\delta_0}, e^{i\delta_2}$ for $I = 0, I = 2$. We can then rewrite expression (16) in the following form:

$$\begin{aligned} \langle \pi^+\pi^-| &= \sqrt{\frac{1}{3}}\,\mathrm{e}^{i\delta_2}\langle \pi\pi, I = 2| + \sqrt{\frac{2}{3}}\,\mathrm{e}^{i\delta_0}\langle \pi\pi, I = 0|, \\ \langle \pi^0\pi^0| &= \sqrt{\frac{2}{3}}\,\mathrm{e}^{i\delta_2}\langle \pi\pi, I = 2| - \sqrt{\frac{1}{3}}\,\mathrm{e}^{i\delta_0}\langle \pi\pi, I = 0|. \end{aligned} \tag{17}$$

Decay amplitudes are determined by the following expressions:

$$\begin{aligned} A_0 &= \langle \pi\pi, I = 0|H_W|K^0\rangle, \\ A_2 &= \langle \pi\pi, I = 2|H_W|K^0\rangle. \end{aligned} \tag{18}$$

Analogous amplitudes for $\bar{K}^0$ can be obtained by using CPT transformation, then $|K^0\rangle \to -\langle \bar{K}^0|$ and

$$\begin{aligned} \langle \pi\pi, I = 0| &\to |\pi\pi, I = 0\rangle, \\ \langle \pi\pi, I = 2| &\to |\pi\pi, I = 2\rangle. \end{aligned} \tag{19}$$

Then on supposition of CPT invariance we get

$$\begin{aligned}\langle \pi\pi, I=0|H_W|\bar{K}^0\rangle &= -A_0^*,\\ \langle \pi\pi, I=2|H_W|\bar{K}^0\rangle &= -A_2^*.\end{aligned} \tag{20}$$

The primary state of kaon beam is some superposition of K^0, $\bar{K}^0$ mesons which have isospin $I = 1/2$. Therefore, transitions described by the amplitude A_2 have $\Delta I = 3/2$ and this violates the rule $\Delta I = 1/2$. It is known that the transitions with $\Delta I = 3/2$ are suppressed by the factor $1/20$.

Using expressions (14)–(20), we can write the amplitudes of observable values via A_0, A_2 and CP-violating parameter ε_0 in the following form:

$$\begin{aligned}
\langle \pi^+\pi^-|H_W|K_S\rangle &= \frac{1}{\sqrt{6}}\left\{\left[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} + \frac{4}{\sqrt{2}}A_0\,\mathrm{e}^{i\delta_0}\right] + \varepsilon_0(A_2 - A_2^*)\,\mathrm{e}^{i\delta_2}\right\},\\
\langle \pi^0\pi^0|H_W|K_S\rangle &= \frac{1}{\sqrt{3}}\{[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} - \sqrt{2}A_0\,\mathrm{e}^{i\delta_0}] + \varepsilon_0[(A_2 - A_2^*)\,\mathrm{e}^{i\delta_2}]\},\\
\langle \pi^+\pi^-|H_W|K_L\rangle &= \frac{1}{\sqrt{6}}\left\{(A_2 - A_2^*)\,\mathrm{e}^{i\delta_2} + \varepsilon_0\left[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} + \frac{4}{\sqrt{2}}A_0\,\mathrm{e}^{i\delta_0}\right]\right\},\\
\langle \pi^0\pi^0|H_W|K_L\rangle &= \frac{1}{\sqrt{3}}\{[(A_2 - A_2^*)\,\mathrm{e}^{i\delta_2}] + \varepsilon_0[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} - \sqrt{2}A_0\,\mathrm{e}^{i\delta_0}]\}.
\end{aligned} \tag{21}$$

Ratios between experimentally observable values are determinated by the following expressions:

$$\begin{aligned}\eta^{+-} &= \frac{\langle \pi^+\pi^-|H_W|K_L\rangle}{\langle \pi^+\pi^-|H_W|K_S\rangle},\\ \eta^{00} &= \frac{\langle \pi^0\pi^0|H_W|K_L\rangle}{\langle \pi^0\pi^0|H_W|K_S\rangle}.\end{aligned} \tag{22}$$

If we neglect the second-order terms of the small values ε_0 and $|A_2|$, then from (21) we get

$$\begin{aligned}\eta^{+-} &\approx \varepsilon_0 + \varepsilon_0',\\ \eta^{00} &\approx \varepsilon_0 - 2\varepsilon_0',\end{aligned} \tag{23}$$

where

$$\varepsilon_0' = \frac{1}{\sqrt{2}}\,\mathrm{Im}\left(\frac{A_2}{A_0}\right)\mathrm{e}^{i(\pi/2+\delta_2-\delta_0)}. \tag{24}$$

The value ε_0' is a direct CP-violating term which does not appear at indirect CP violation in the system of K^0, $\bar{K}^0$ mesons [1].

2.2. New Result Obtained by Using the Standard Theory of Oscillations. At big distance ($t \geqslant 6\tau_S$) all primary K_S mesons have time to decay and then there will be present only K_S mesons which are created at K_2^0 oscillations. From expressions for K_1^0-, K_2^0-meson oscillations we see that there cannot appear direct CP violation. Direct CP violation can appear only at direct decays of K_2^0 mesons. Now we consider the case of direct CP violation when the standard theory of oscillations is used.

For this aim we will use expressions (14)–(20). The expression for amplitudes of K_1^0-, K_L-meson decays into two pions can be written (by using A_0, A_2 and CP-violating parameter β) in the following form [3] (here we suppose that at transition $K_2^0 \to K_1^0$ the K_L state is generated):

$$\langle\pi^+\pi^-|H_W|K_1^0\rangle = \frac{1}{\sqrt{6}}\left[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} + \frac{4}{\sqrt{2}}A_0\,\mathrm{e}^{i\delta_0}\right],$$

$$\langle\pi^0\pi^0|H_W|K_1^o\rangle = \frac{1}{\sqrt{3}}[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} - \sqrt{2}A_0\,\mathrm{e}^{i\delta_0}], \qquad (25)$$

$$\langle\pi^+\pi^-|H_W|K_L\rangle = \frac{1}{\sqrt{6}}\Big\{\cos\,\beta(A_2 - A_2^*)\,\mathrm{e}^{i\delta_2} + $$
$$+\sin\,\beta\left[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} + \frac{4}{\sqrt{2}}A_0\,\mathrm{e}^{i\delta_0}\right]\Big\},$$

$$\langle\pi^0\pi^0|H_W|K_L\rangle = \frac{1}{\sqrt{3}}\{\cos\,\beta[(A_2 - A_2^*)\,\mathrm{e}^{i\delta_2}] + $$
$$+\sin\,\beta[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} - \sqrt{2}A_0\,\mathrm{e}^{i\delta_0}]\}.$$

Taking into account that $\cos\,\beta \simeq 1$ and introducing the notation $\sin\,\beta = \varepsilon$ (then the parameter of CP violation is $\epsilon = \sin^2\beta$), we can rewrite expression (25) in the following form:

$$\langle\pi^+\pi^-|H_W|K_1^0\rangle = \frac{1}{\sqrt{6}}\left[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} + \frac{4}{\sqrt{2}}A_0\,\mathrm{e}^{i\delta_0}\right],$$

$$\langle\pi^0\pi^0|H_W|K_1^0\rangle = \frac{1}{\sqrt{3}}[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} - \sqrt{2}A_0\,\mathrm{e}^{i\delta_0}], \qquad (26)$$

$$\langle\pi^+\pi^-|H_W|K_L\rangle = \frac{1}{\sqrt{6}}\left\{(A_2 - A_2^*)\,\mathrm{e}^{i\delta_2} + \varepsilon\left[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} + \frac{4}{\sqrt{2}}A_0\,\mathrm{e}^{i\delta_0}\right]\right\},$$

$$\langle\pi^0\pi^0|H_W|K_L\rangle = \frac{1}{\sqrt{3}}\{[(A_2 - A_2^*)\,\mathrm{e}^{i\delta_2}] + \varepsilon[(A_2 + A_2^*)\,\mathrm{e}^{i\delta_2} - \sqrt{2}A_0\,\mathrm{e}^{i\delta_0}]\}.$$

The expression for relation between amplitudes (for experimentally observable values) for $K_L \to \pi^+\pi^-$ and $K_1^0 \to \pi^+\pi^-$ decays and the expression for relation between amplitudes of their decay into two neutral pions look as follows:

$$\begin{aligned} \eta_1^{+-} &= \frac{\langle \pi^+\pi^- | H_W | K_L \rangle}{\langle \pi^+\pi^- | H_W | K_1^0 \rangle}, \\ \eta_1^{00} &= \frac{\langle \pi^0\pi^0 | H_W | K_L \rangle}{\langle \pi^0\pi^0 | H_W | K_1^0 \rangle}. \end{aligned} \tag{27}$$

If we neglect the second-order terms of ε and $|A_2|$ (since they are small values), then from (25) or (26) we get

$$\begin{aligned} \eta_1^{+-} &\approx \varepsilon + \varepsilon', \\ \eta_1^{00} &\approx \varepsilon - 2\varepsilon', \end{aligned} \tag{28}$$

where

$$\varepsilon' = \frac{1}{\sqrt{2}} \, \mathrm{Im} \left(\frac{A_2}{A_0} \right) \mathrm{e}^{i(\pi/2 + \delta_2 - \delta_0)}.$$

It is necessary to keep in mind that in the approach where the standard theory of oscillations is used [3] $\varepsilon = \sin\beta$ and then the parameter of CP violation ϵ is $\epsilon = \sin^2\beta$ in contrast to the old result where these parameters are the same. The value ε' is a new direct CP-violating parameter which does not coincide with the old direct CP-violating parameter ε'_0 [1].

Now ratios between experimentally observable values, in contrast to the old case, are given by the following relations:

$$\begin{aligned} |\eta^{+-}|^2 &= \left| \frac{\langle \pi^+\pi^- | H_W | K_L \rangle}{\langle \pi^+\pi^- | H_W | K_1^0 \rangle} \right|^2 \approx (\varepsilon + \varepsilon')^2 = \varepsilon^2 + 2\varepsilon\varepsilon', \\ |\eta^{00}|^2 &= \left| \frac{\langle \pi^0\pi^0 | H_W | K_L \rangle}{\langle \pi^0\pi^0 | H_W | K_1^0 \rangle} \right|^2 \approx (\varepsilon - 2\varepsilon')^2 = \varepsilon^2 - 4\varepsilon\varepsilon'. \end{aligned} \tag{29}$$

In the above expressions we neglected the term ε'^2, supposing that $\varepsilon^2 \ll \varepsilon'^2$. We remind that ε^2 is the parameter of CP violation and $\epsilon = \varepsilon^2$. Then

$$\frac{|\eta^{00}|^2}{|\eta^{+-}|^2} \approx \frac{\varepsilon^2 - 4\varepsilon\varepsilon'}{\varepsilon^2 + 2\varepsilon\varepsilon'} = 1 - 6\frac{\varepsilon'}{\varepsilon},$$

or

$$R = \frac{|\eta^{00}|^2}{|\eta^{+-}|^2} \approx 1 - 6\frac{\varepsilon'}{\sqrt{\epsilon}}, \tag{30}$$

where ϵ is the parameter of CP violation.

In work [4] a value for $\mathrm{Re}\left(\frac{\varepsilon'}{\varepsilon}\right)$ was obtained and it is equal to

$$\mathrm{Re}\left(\frac{\varepsilon'}{\varepsilon}\right) = \frac{1-R}{6} = (14.7 \pm 2.2) \cdot 10^{-4}.$$

Taking into account that [5] $\epsilon = 2.23 \cdot 10^{-3}$ ($\sqrt{\epsilon} = 4.72 \cdot 10^{-2}$), for the old case we have

$$\varepsilon' = 32.78 \cdot 10^{-7}. \tag{31}$$

For our case for ε' we obtain

$$\varepsilon' = 69.38 \cdot 10^{-6}. \tag{32}$$

3. CONCLUSION

In work [3], in the framework of the standard theory of oscillations, we considered K^0-, K^0-meson mixings and oscillations via K_1^0-, K_2^0-meson states at strangeness violation by the weak interactions and K_1^0-, K_2^0-meson mixings and oscillations via K_S-, K_L-meson states at CP violation by the weak interactions without and with taking into account decay widths. It was realized in the framework of the masses mixing scheme.

In this work we computed the parameter of direct CP violation by the weak interactions at K_1^0-, K_2^0-meson mixings and oscillations via K_S-, K_L-meson states in the framework of the above-mentioned approach. This direct CP violation appears owing to the presence of CP-violation term with isospin $I = 2$.

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